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INFLUENCE OF HYDROGEN PEROXIDE ON LIQUEFIED PETROLEUM GAS (LPG) PERFORMANCE

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ABSTRACT

The objective of this study is to investigate the effects of hydrogen peroxide (H_2O_2) on the combustion enhancer and performance of liquefied petroleum gas (LPG) on spark ignition engines. LPG has a simpler hydrocarbon structure than conventional fuels. H_2O_2 is recently reported as a renewable fuel and to be a low-emission high-quality fuel replacement. The addition of H_2O_2 at various wt. percentage concentrations in to LPG at mixture (LPG/H_2O_2) form will be used for the experiments and measurements can be made to study the performance, combustion, and emissions characteristics. The performance of in starting from lean LPG until obtaining a better composition can reduce the LPG fuel consumption. The theory behind this concept is that the addition of hydrogen peroxide can extend the lean operation limit, improve the lean burn ability, decrease burn duration and controlling the exhaust emission by reducing green house gaseous.

Keywords: LPG, H_2O_2, Air-fuel ratio, exhaust emission

INTRODUCTION

With increasing concern on the effect of air pollution on environment, animal and plant life, particularly in the field of road transport, vehicle exhaust emissions have in recent years, been subjected to increasingly stringent regulations. The automotive engineering has undergone continuous changes and improvements, but at the same time, various global environmental issues related to vehicle use are becoming more serious. With the increasing need both to conserve fossil fuel and to minimize toxic emission so called green house gaseous. Very much focus and efforts are made for the advancement of current combustion technology. The pollution level recorded in large urban areas are rising concern for public health and substantial reduction or decrease in pollutant emissions have become an important topic(Evans, 2007). LPG is considered to be one of the most promising alternative fuels not only as a substitute for petroleum but also as a means of reducing CO_x, NO_x, soot and particulate matter. Fuels like vegetable oils, which have a high cetane number, can be directly used in neat form in a conventional diesel engine. Alcohols like ethanol also can be used in a neat form with ignition improvers like diethyl ether (DEE) or by employing hot surfaces for ignition (Nagarajan et al., 2002). LPG has a high octane rating and is therefore well suited for SI engine. However, when LPG is burnt in the conventional diesel engine there is a difficulty in self-ignition because of its lower cetane number. If LPG is to be used as an alternative to diesel, the cetane rating needs to be improved with additives or other positive means of initiating combustion. Adding a cetane number improver to LPG is one method to improve its cetane number and its ignition quality. One of the authors suggested that free radicals produced by the thermal decomposition of a diesel engine cycle have an important role in improving the ignition property(Hashimoto et al., 2002). Besides that, H_2O_2 had been used as rocket propellant fuel in a past (HPF, 2005). It can also be used to run automobiles it worked as an alternative or replacement for hydrogen gas. Because Hydrogen infrastructure is very hard to achieve, similarly acquiring a hydrogen economy is also difficult to attain (HPF, 2005). Hydrogen peroxide is viable, alternative energy storage medium, competing with hydrogen gas. H_2O_2 is an energy-dense fuel that burns as cleanly as H_2, but requires no oxidizer as it is included inside the fuel. Actually, it does not burn; it decomposes, with a release of tremendous energy, close to the energy per mole of H_2. It is like water, so it does not need a pressure vessel to contain it (Gentle et al., 2001). Over about 80% H_2O_2 (where H_2O_2 is the impurity), it is explosive and extreme mechanical shock or heat can set it off. It is "burned" in jets and other devices by catalytic decomposition. We can get 3500-psi steam out of it! Helicopters have flown with rotors containing H_2O_2 jets on their blade tips - no tail rotors are needed and no central engine. Very cheap and simple fuel is possible with peroxide.

Various researchers have conducted tests with fuel blends of DME added to propane (LPG) (Kajitani et al., 1998), natural gas (Zhili et al., 2000), and n-butane (Lida and Igarashi, 2000). DME shows a zero level in NO_x emissions and a good ignition quality as an ignition additive in homogeneous charge compression ignition HCCI LPG engine (Alam et al., 2001). Performance and emissions of a DI diesel engine operated with LPG and ignition improving additives (Goto et al., 1999). Experiments in a direct injection LPG diesel engine have been conducted using di-tertiary-butyl peroxide (DTBP) as an ignition additive. With 1% and 15%, DTBP addition the cetane rating of LPG was found to be about 48 and 60, respectively (Zhili et al., 2000). The main advantage of the present work is that the maximum blending of H_2O_2 in to LPG. In addition, the LPG/ H_2O_2 fuel pipeline, fuel pump and fuel injector can be completely modified from the four-stroke engine. The properties of LPG and H_2O_2 are shown in Table 1

Table 1: Physical properties of propane, Butane and Hydrogen Peroxide(Lida and Igarashi, 2000).

Property	Propane	Butane	Hydrogen peroxide
Formula	C_3H_8	C_4H_{10}	H_2O_2
Density (kg/m^3)	505	600	0.001463 Kg/cm^3
Viscosity at 20 °C (centipoise)	—		1.245 cP (20 °C)
Boiling point (°C)	−42.09 °C	0.5 °C (	150.2 °C,423 K,302 °F
Cetane number	<3		
Auto-ignition temperature (°C)	465	500 °C	Non-flammable
Stoichiometric air fuel mass ratio	15.6	14.37	N.A.
Flammability limits, rich (vol%)	15.7	N.A	1518 mg/kg
Flammability limits, lean (vol%)	9.5	N.A	—
Calorific value (kJ/kg)	101,000	49,510	
Specific heat capacity(J/kgK)	1630	1675	2.619 J/g K (liquid)

THEORY

In order to properly understand the effect of adding hydrogen peroxide to enrich hydrocarbon combustion it is important to understand the basics of how an internal combustion cycle works. Figure 1 shows a diagram of a four-stroke engine. The four-stroke engine cycle is made up of four phases: Induction, compression, power and exhaust.

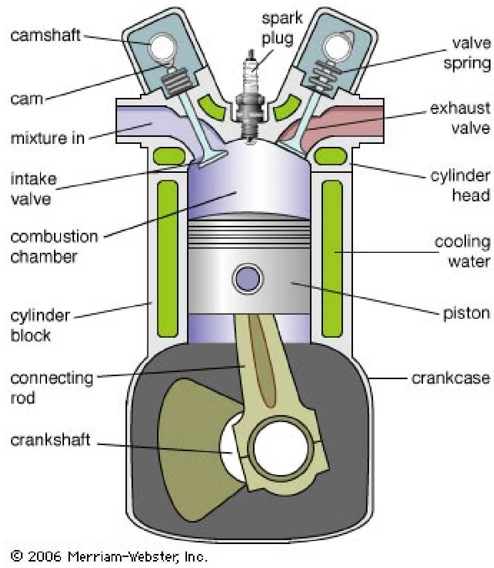

Figure 1: Four stroke internal-combustion engine

In the power stroke, the fuel burns causing the pressure and temperature to rise driving the piston downward. This generates the rotation of the crankshaft. At the end of the power stroke, the exhaust valve opens.In the exhaust stroke, the rotation of the crankshaft causes the piston to move up pushing the exhaust out the open exhaust valve. At the end of the exhaust stroke, the exhaust valve closes. The cycle is then ready to repeat. In the experimentation and performance analysis of an engine, several parameters are needed to quantify the results. Some of these parameters include air/fuel ratio, equivalence ratio, power, thermal efficiency, fuel consumption, and emissions (Gentle et al., 2001).

Air-fuel ratio (AFR)

AFR is the mass ratio of air to fuel present during combustion. When all the fuel is combined with all the free oxygen, typically within a vehicle's combustion chamber, the mixture is chemically balanced and this AFR is called the stoichiometric mixture (often abbreviated to stoich). AFR is an important measure for anti-pollution and performance tuning reasons. Lambda (λ) is an alternative way to represent AFR.

$$AFR = \frac{m_{air}}{m_{fuel}} \tag{1}$$

The Air fuel ratio is the most common reference term used for mixtures in internal combustion engines(HPF, 2005).

Equivalence Ratio

The equivalence ratio of a system is defined as the ratio of the fuel-to-oxidizer ratio to the stoichiometric fuel-to-oxidizer ratio. Mathematically,

$$\phi = \frac{\text{fuel-to-oxidizer ratio}}{(\text{fuel-to-oxidizer ratio})_{st}} = \frac{m_{fuel}/m_{ox}}{(m_{fuel}/m_{ox})_{st}} = \frac{n_{fuel}/n_{ox}}{(n_{fuel}/n_{ox})_{st}} \tag{2}$$

where, *m* represents the mass, *n* represents number of moles, suffix *st* stands for stoichiometric conditions (Gentle et al., 2001).

Thermal Efficiency

When transforming thermal energy into mechanical energy, the thermal efficiency of a heat engine is the percentage of heat energy that is transformed into work(Gentle et al., 2001).

Thermal efficiency is defined as:

$$\eta_{th} \equiv \frac{W_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}} \tag{3}$$

where, *n* represents the efficiency, W_{out} represent work done, suffix Q_{in} stands for Heat input, Q_{out} stands for Heat output (HPF, 2005).

Fuel Efficiency

Fuel efficiency is a form of thermal efficiency, meaning the efficiency of a process that converts chemical potential energy contained in a carrier fuel into kinetic energy or work. Overall fuel efficiency may vary per device, which in turn may vary per application. In the context of transport, "fuel efficiency" more commonly refers to the energy efficiency of a particular vehicle model, where its total output (range, or "mileage") (HPF, 2005). The emissions of an engine are determined by the operating conditions of the engine. The main emissions of an engine are nitrogen oxides, carbon oxides, and unburned hydrocarbons.

NO_x

Nitrogen oxidizes are generally formed at high temperatures (around 1500 C) when N2 is oxidized in air. The Zeldovich Mechanism governs this reaction, see Equations 4-6. Typically, if combustion temperature and residence time are minimized and the appropriate amount of air is used NO emissions will be small work (Gentle et al., 2001).

$$O_2 \rightleftharpoons O + O \tag{4}$$

$$O + N_2 \underset{k_1}{\overset{k_1}{\rightleftharpoons}} O + NO \tag{5}$$

$$O_2 + N \underset{k_1}{\overset{k_1}{\rightleftharpoons}} O + NO \tag{6}$$

CO_x

Carbon dioxide is the product of complete combustion. If sufficient oxygen is present then CO will be oxidized to CO_2. Carbon monoxide emissions are more likely to occur during rich mixture conditions work (Gentle et al., 2001).

Unburned Hydrocarbon

Unburned hydrocarbons are created due to several conditions in the combustion process. In regions of the flame near the surfaces of the combustion chamber, the heat lost through the chamber wall is greater than the heated needed to sustain a flame. This condition causes areas of quenched flame where hydrocarbons are left unburned.Hydrogen peroxide, H_2O_2, is an environmentally friendly compound exhibiting well-known bactericide and oxidizing properties.

EXPERIMENTAL DESIGN & SET-UP

Material includes the H_2O_2 with the concentratation of at least 50 percent from MERCK Company from Germany. LPG contains 30% butane (both iso and normal) and 70% of propane.LPG is the abbreviation of Liquefied Petroleum Gas. This group of products includes saturated Hydrocarbons, Propane (C_3H_8), and Butane (C_4H_{10}), which can be stored separately or as a mixture. They exist as gases at normal room temperature and atmospheric conditions. The composition of LPG and H_2O_2 will be analyzed. According to our plan, LPG sample contains 30% butane (both iso and normal) and 70% of propane. We can introduce H_2O_2 in various compositions for obtaining better result and gaining optimum conditions for both performance and emission control. We have a plan to use Gas combustion unit and Gas explosion unit to examine the performance of LPG/H_2O2 mixture in various compositions starting from lean LPG until obtaining a better composition.

$$H_2O_2 \xrightarrow{\text{catalyst}} H_2O\text{ (steam)} + \tfrac{1}{2}O_2 + \text{heat} \tag{7}$$

LPG is a mixture of two gases:

Propane (C_3H_8) & Butane (C_4H_{10}) in various proportions.
The equations of the reactions are as follows:
For Propane Equation becomes:

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O\text{ (steam)} + \text{heat} \tag{8}$$

This reaction require air fuel ratio of 15.6:1. It means for every mole of propane requires 15.6 moles of air.

For butane, Equation becomes:

$$C_4H_{10} + 6O_2 \longrightarrow 4CO_2 + 4H_2O\text{ (steam)} + \text{heat} \tag{9}$$

This reaction require air fuel ratio of 14.37:1. It means for every mole of butane requires 14.37 moles of air.

As LPG is mixture of propane and butane, we will use it in a composition of 70% propane and 30% butane. Therefore, the actual air fuel ratio of LPG will be 15.23:1. It means for every mole of LPG requires 15.23 moles of Air.

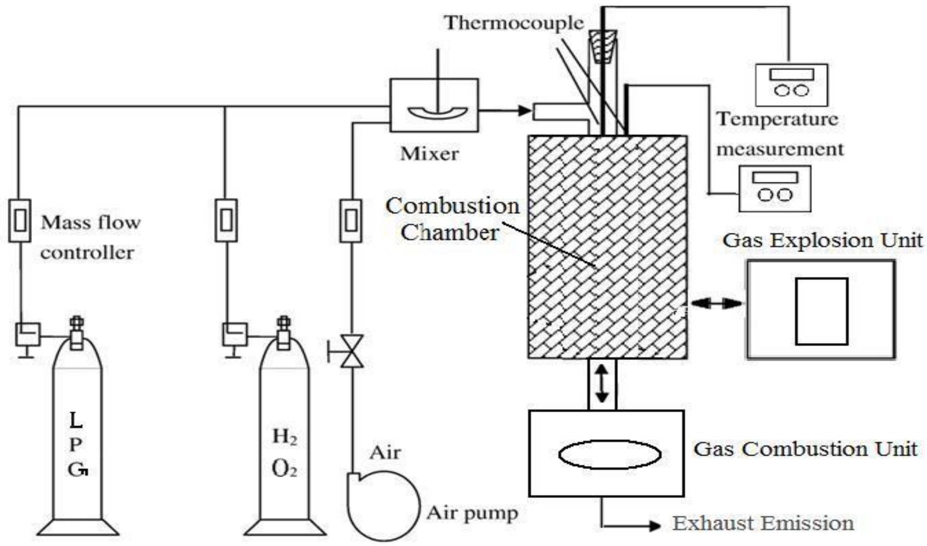

Figure 2: Schematic flow diagram LPGH_2O_2 combustion system

CONCLUSIONS/ EXPECTED RESULTS

In this study, we are expecting that the hydrogen peroxide be added to LPG will improve the ignition and burn off. Furthermore, the combustion products of hydrogen peroxide containing LPG will be tested. The following conclusions may be draw from the study:

- Hydrogen peroxide could decrease the ignition temperature and burn off temperature of LPG evidently for a wide concentration range. The initial and final temperature may decreases continuous with the increase of hydrogen peroxide. For one vol percentage LPG combustion, the initial and final temperature could be decreases to 40 °C and 37 °C when the H_2O_2/LPG is equal to 0.05. The initial and final temperature could be decreases about 130 °C and 140 °C when the H_2O_2/LPG ratios are 2.5.

- CO generation could be decreases during combustion in a wider temperature range when the hydrogen peroxide is add because excessive oxygen of hydrogen peroxide may reduces the emission of carbon monoxide in the form of carbon dioxide.

- Silver catalyst could improve the conversion of hydrogen peroxide that will produce enormous amount of energy also improve the ignition and burn off, which ultimately enhance the efficiency of the system. Furthermore, we also have a plan to analysis the combustion products of hydrogen peroxide containing LPG.

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